DTU Library

Properties of Commercial PVC Films with Respect to Electron Dosimetry

Miller, Arne; Liqing, Xie

Publication date:
1985

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):
Miller, A., & Liqing, X. (1985). *Properties of Commercial PVC Films with Respect to Electron Dosimetry*. Risø National Laboratory. Risø-M No. 2508

DK8500118

Risø-M-2508

RISØ

Properties of Commercial PVC Films with Respect to Electron Dosimetry

Arne Miller, Xie Liging

RISØ-M-2508

Properties of Commercial PVC-Films with Respect to Electron Dosimetry

Arne Miller and Xie Liqing
Accelerator Department

Abstract. The properties of three commercially available polyvinyl chloride (PVC) film supplies and one made without additives were tested with respect to their application as routine dose monitors at electron accelerators. Dose fractionation was found to increase the response and the post-irradiation heat treatment was very critical for some of the films.

INIS-Descriptors: COLORIMETRIC DOSEMETERS; FRACTIONATED IRRADIATION; LINEAR ACCELERATORS; PVC; RADIATION DOSES; STABILITY; TEMPERATURE DEPENDENCE

May 1985
Risø National Laboratory, DK 4000 Roskilde, Denmark

ISBN 87-550-1118-7
ISSN 0418-6435

Grafisk Service Center, Risø 1985

CONTENT

1. INTRODUCTION

The use of electron accelerators for radiation sterilization requires the recording of several key parameters such as conveyor speed, beam current, electron energy, and scanner width in order to document that each product box receives the proper absorbed dose. (IAEA, 1967, Frohnsdorff and Peter, 1977, Eucomed, 1984). As a supplement, the dose to individual boxes may be recorded by dosimeters affixed to the boxes.

When dosimetry is used to monitor and control the sterilization process, plastic films in the form of long strips are used to cover the full width of product boxes. Either colouration or fading of colour, as a result of irradiation, may be used as a measure of the absorbed dose. Some plastic films that can serve for this purpose include blue cellophane (fading, visible) (Gehringer et al., 1982); cellulose triacetate (coloration, UV) (Tanaka et al., 1984); polyethylene (colouration, UV or IR) (Chen et al., 1980, Charlesby et al., 1964) polyvinyl chloride (colouration, UV or visible) (Ilic-Popović, 1966), and several other film materials (McLaughlin et al., 1979, 1983).

At Risø National Laboratory, PVC (polyvinyl chloride) has been used for many years to control the absorbed dose, when radiation sterilization is carried out at the 10-MeV linear accelerator. PVC may hardly be called a true dosimeter, because its colouration depends strongly on irradiation conditions (Miller et al., 1975), but it offers the advantage of low price, a visible colouration and reasonable reproducible response when used as a dose monitor under identical or near-identical conditions. Calibration of response-versus-dose must therefore be carried out only under irradiation and environmental conditions, the same as those under which the films are later used routinely. A further disadvantage of PVC is the requirement of a controlled heat treatment after irradiation, in order to develop and stabilize the radiation induced-colour. This treatment is typically 80°C for 30 min. shortly after irradiation.

The colouration of PVC depends strongly on the presence of additives such as anti-oxidants and plasticizers, and PVC films from different producers are almost certain to produce different absorption spectra and colour intensities; even different batches from the same producer may also show large differences.

2. PURPOSE

The purpose of this investigation is to test three commercial PVC-films with respect to properties of interest for routine electron-beam dosimetry use. One film, made at Risø of pure PVC without additivies, is included in the investigation.

The investigation includes:

a) Comparison of irradiations to absorbed doses of 10, 20, 30, 40, and 50 kGy given in separated fractions of 10 kGy with those given as uninterrupted single doses of the same total values.

b) Comparison of different post-irradiation heating times at 80°C.

c) Comparison of different post-irradiation heating temperatures for 30 minutes.

d) Test of stability after irradiation of radiation-induced absorbance at 395 nm wavelength.

3. EXPERIMENTAL DESCRIPTION

In the product-irradiation mode, the beam of the 10-MeV linear accelerator at Risø is directed vertically downwards towards a moving conveyor belt. The dose is set by adjusting the conveyor speed, and calibration of the speed-versus-absorbed dose is achieved by means of calorimetry (Miller, 1984; Miller and Kovacs, 1985).

The parameters of the linear accelerator for typical radiation processing conditions are:

Energy : 10 MeV
Pulse current : 1.2 A
Pulse length : 4 μs
Pulse frequency : 200 pps
Scanner frequency: 5 Hz
Scanner width : 60 cm
Conveyor speed
at 10 kGy: 1.6 $m \cdot min^{-1}$.

The strips of 1 cm wide PVC were placed in an aluminum carrier tray under a cardboard box filled with plastic foam, which served as a dummy product box. This simulated the practical application of the PVC-films, where the strips are used to control proper penetration of the radiation through boxes containing low bulk-density products. Care was taken not to use Al-trays that had recently been heated as a result of previous irradiation.

The PVC-film strips were read at a Pye-Unicam SP 8-400 spectrophotometer. Three of the the PVC-films were supplied as:

Batch A: Rianyl, thickness 0.25 mm
Rias, Roskilde, Denmark.

Batch B: PVC-foil, thickness 0.25 mm
Forenede Plast A/S, Kirke Såby, Denmark.

Batch C: PVC-film (Roll-1), thickness 0.3 mm
Jysk Vacuum Plast, Esbjerg, Denmark.

In addition, we used:

Batch D: Pure PVC-foil, made by dissolving PVC-powder in tetrahydrofuran and casting the solution on a plane glass surface and later stripping the dried film. Thickness 0.1 mm.

The doses were measured with a water calorimeter, which was irradiated immediately after the PVC-films, and doses are stated here as measured with the calorimeter, i.e. as dose to water.

4. RESULTS

Typical absorption spectra of the 4 different unirradiated and irradiated (30 kGy) PVC-films are shown in Fig. 1 a-d. The wavelength normally used for routine measurements is 395 nm at the peak of one of the absorption bands, which are known to be due to polyene unsaturations (double bands) due to radiation-induced crosslinking of the polymer (Charlesby, 1960).

The absorption spectrum for the unstabilized PVC (batch D) is very different from the spectra of the stabilized types, and it seems preferable to choose different wavelengths for routine measurements with this film. However, for the purpose of the intercomparison, 395 nm is used for all 4 films.

Fig. 1 indicates the relative sensitivity of the 4 PVC-films to electron-beam irradiation, A being the least sensitive and D the most.

The response to single doses of radiation compared with that to fractionated doses is shown in Figs. 2a and 2b. The general trend is that fractionated doses result in a higher response than uninterrupted single doses. This emphasizes the previous statement that a calibration of PVC-films is valid under only a given set of irradiation conditions.

In the measurements above, the PVC-films were given a heat treatment of 80°C for 30 min. immediately after irradiation. The importance of the timing of this heat treatment was tested in a separate experiment by waiting 2 days before applying the heat treatment. For batches A and C there was no difference in the response, but for batch B the response was 6% higher, and for D it was 10-20% higher.

The stability of the radiation-induced colour was tested for the irradiated films shown in Figs. 2a and 2b by repeating the measurements 6 and 20 days after the first measurements. Batches A and B were almost constant with storage time, while C increased 8% over 20 days, and D increased approx. 10% over 20 days.

Error bars on Figs. 2a and 2b indicate the maximum deviation of measured values from the average value. The average standard error of the mean value for batches A and B was generally of the order of ±5%, while for C it was approx. ±10% and for D up to ±15%.

The need for a precise heat treatment was tested by treating three of the films after irradiation at 80°C for 20, 30, and 45 min. and at 60°, 80°, and 100°C for 30 min. Figure 3 shows the variation of response for batches A, B, C for the different heating times. The time does not seem to be critical over the 20-45 min. period for batch A, a minimum of 30 min. must be maintained for B, while C does not seem to have stabilized even after 45 min.

The variation of response for batches A, B, and C for different heating temperatures is shown in Fig. 4. 80°C seems to be adequate for batch A, while both for batches B and C 100°C gives a stronger colour.

5. FURTHER MEASUREMENTS

Based on the above observations batch A was chosen as a dosimeter film for routine use at the 10-MeV electron accelerator. Batch A had slightly better properties than B although the radiation sensitivity was somewhat smaller. A larger supply was therefore ordered and tested (batch A-1). The nominal thickness was again 0.25 mm, but a sample of 0.5 mm thickness was also tested (batch A-2).

The results are shown in Fig. 5. Although batch A-1 nominally was the same PVC-film as batch A, the responses of the two batches are distinctly different. The two-times thicker batch (A-2) proved to be 4 times more sensitive in terms of change in optical density than batch A and A-1, and further experiments may show if this thick PVC-film is to be preferred as a routine dosimeter film for electron-beam dose monitoring.

6. CONCLUSIONS

Three commercial PVC-films and one film made in our laboratory were tested for their properties with respect to their application as routine dosimeters at an electron accelerator. The most sensitive of the three commercial films (batch C) may be the most difficult to use, because of its poorer precision and its dependence on very precise heat treatment. The two other commercial batches (A and B) seem nearly equivalent, but their poorer sensitivity may be a problem, because a direct visual check that the radiation process is progressing within specifications, often valuable to the accelerator operator, may not be possible with these films. A thicker film may therefore be of interest or a specially made pure PVC-film without additives may be used. The poor precision of the pure film tested in these measurements is ascribed to inadequate casting, which caused large thickness variations and surface imperfections.

Although PVC-film may be usable as a routine dose monitor for electron beams, it may be used only under specified irradiation and post-irradiation conditions. A cheap dosimeter, which is available in large volumes and which is independent of irradiation conditions, would be highly desirable.

7. REFERENCES

Charlesby, A. (1960), Atomic Radiation and Polymers. Pergamon Press, New York.

Charlesby, A., Gould, A.R., and Ledbury, K.J. (1964), Comparison of alpha and gamma radiation effects in polyethylene. Proc. Roy. Soc. (London) A277, 348.

Chen, W., Jia, M., Lu, X., Lin, D, and Bao, H. (1980), On Polyethylene Film Dosimeter. Radiat. Phys. Chem. 16, 195-199.

Eucomed (1984), Recommendations for the Sterilization of Medical Devices and Surgical Products. European Confederation of Medical Suppliers Associations, 84/5.

Frohnsdorff, R.S.M. and Peter K.H. (1977), "The Control of Radiation Sterilization Facilities". Radiat. Phys. Chem. 10, 55-60.

Gehringer, P., Proksch, E., and Eschweiler, H. (1982), The γ-radiation response of blue cellophane films under controlled humidity conditions. Int. J. Appl. Radiat. Isot. 33, 27-32.

IAEA (1967), Recommended Code of Practice for the Radiosterilization of Medical Products. In "Radiosterilization of Medical Products", STI/PUB/157, IAEA, Vienna.

Ilić-Popović, J. (1966), The Use of Polyvinyl-Chloride Film for Electron Beam Dosimetry. Danish Atomic Energy Commission Research Establishment Risø, Risø Report No. 141.

McLaughlin, W.L., Humphreys, J.C., Radak, B.B., Miller, A., and Olejnik, T.A. (1979), The Response of Plastic Dosimeters to Gamma Rays and Electrons at High Absorbed Dose Rates. Radiat. Phys. Chem. 14, 535-550.

McLaughlin, W.L., Uribe, R.M., and Miller, A. (1983), Megagray Dosimetry. Radiat. Phys. Chem. 22, 333-362.

Miller, A., Bjergbakke, E., McLaughlin, W.L. (1975), Some Limitations in the Use of Plastic and Dyed Plastic Dosimeters. Int. J. Appl. Radiat. Isot. 26, 611-620.

Miller, A. (1984), Dose Calibrations of Industrial Electron Accelerators. J. of Indust. Irradiation Techn. 2, 367-383.

Miller, A. and Kovacs, A. (1985), Calorimetry at Industrial Electron Accelerators. Nucl. Instr. Meth., to be published.

Tanaka, R., Mitoma, S., and Tamura, N. (1984), Effects of Temperature, Relative Humidity and Dose Rate on the Sensitivity of Cellulose Triacetate Dosimeters to Electrons and γ-rays. Int. J. Appl. Radiat. Isot. 35, no. 9, 875-881.

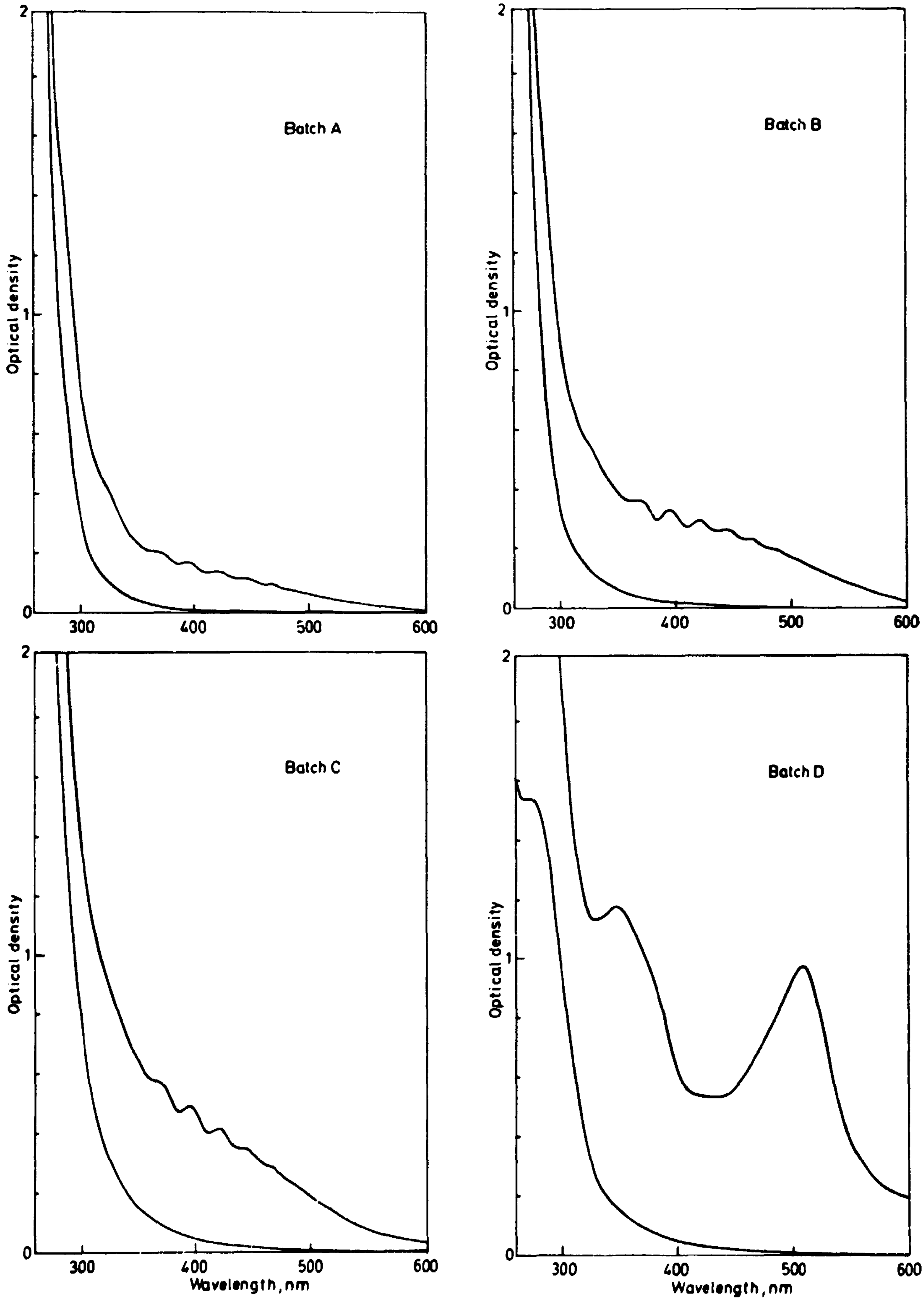

Fig. 1. Absorption spectra for unirradiated PVC-films and for films irradiated to 30 kGy. Batch A, B, C, and D.

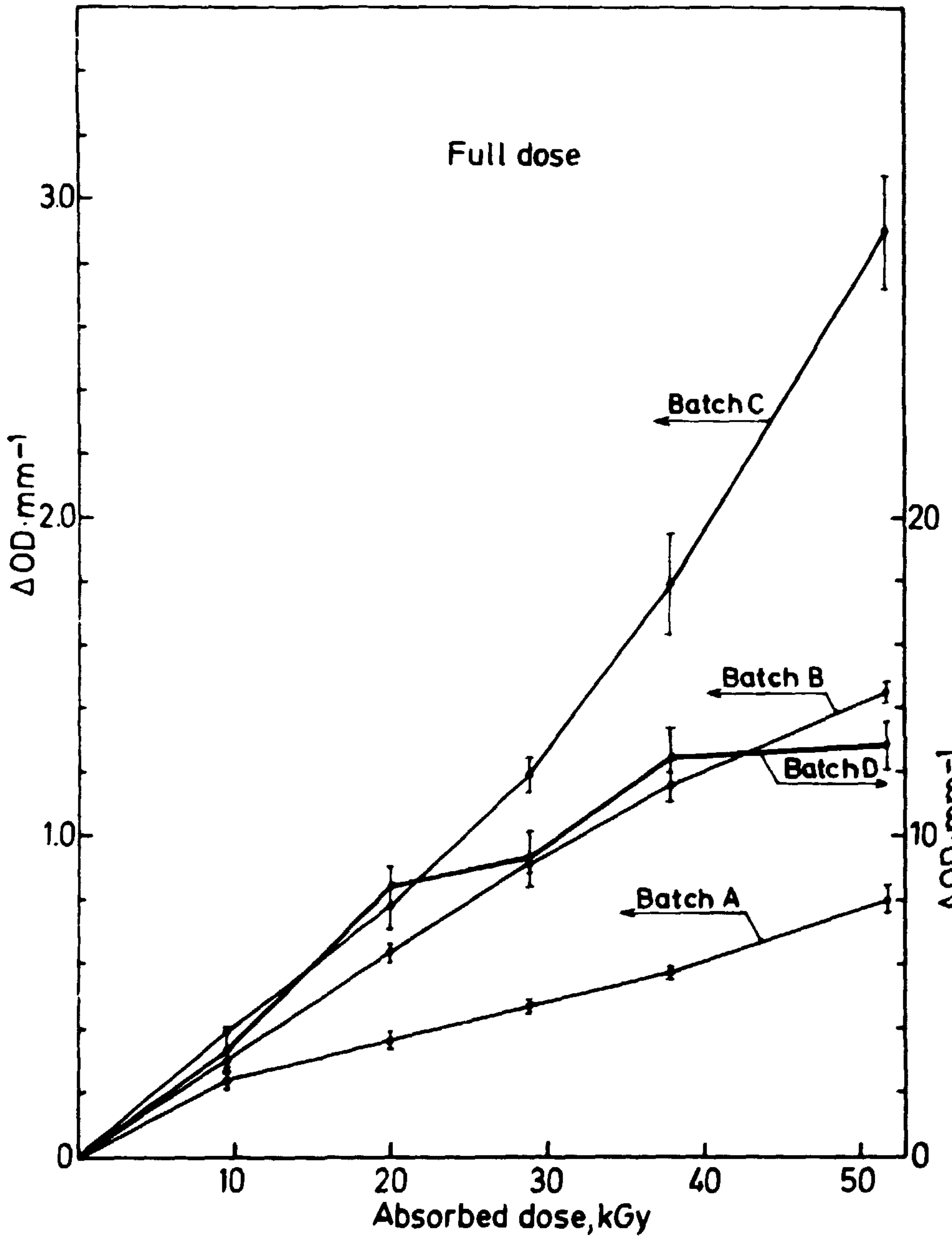

Fig. 2a. Change in optical density divided by thickness (ΔOD·mm^{-1}) versus dose for the 4 PVC-films. The dose in full doses.

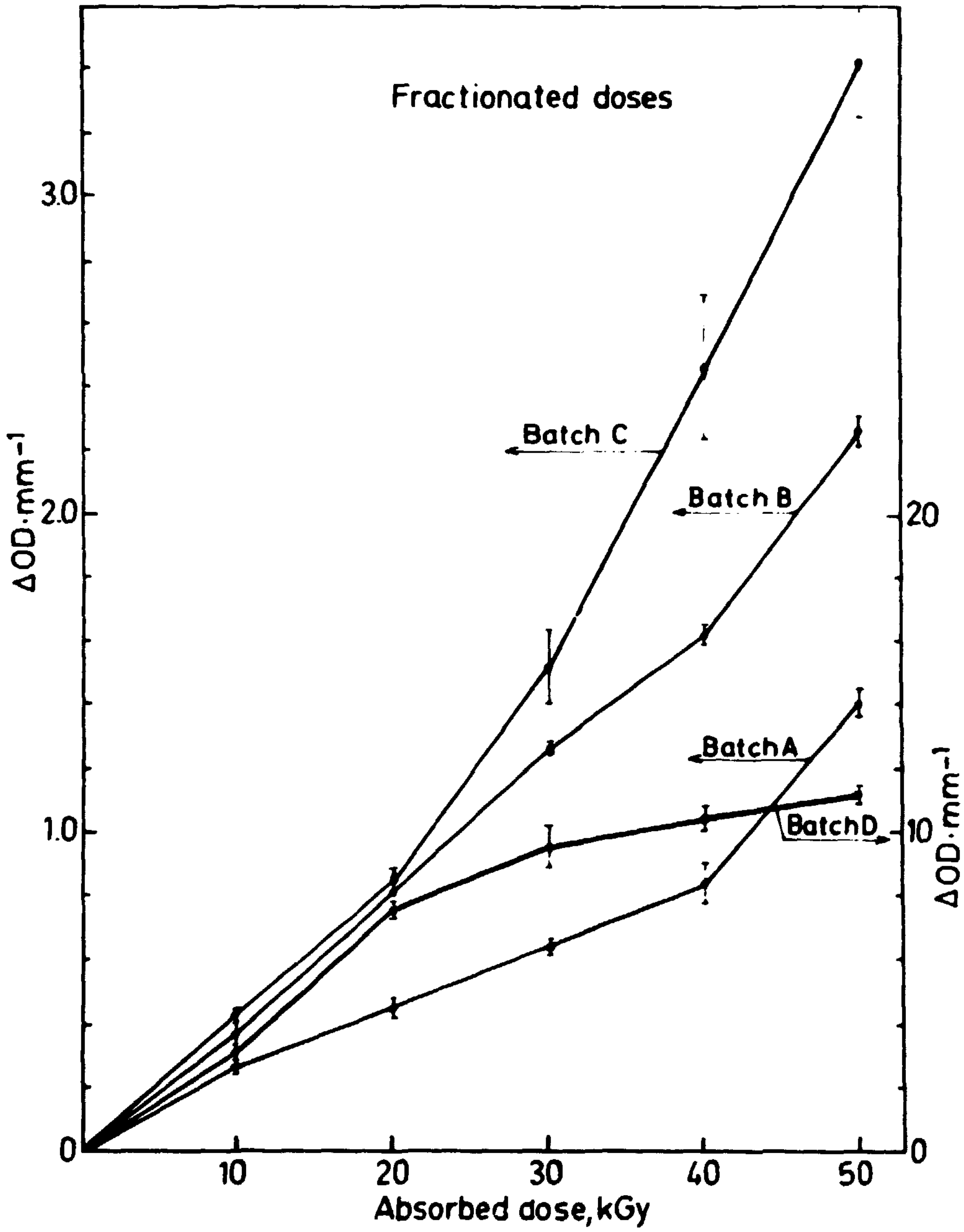

Fig. 2b. Change in optical density divided by thickness ($\Delta OD \cdot mm^{-1}$) versus dose for the 4 PVC-films. The dose in fractions of 10 kGy.

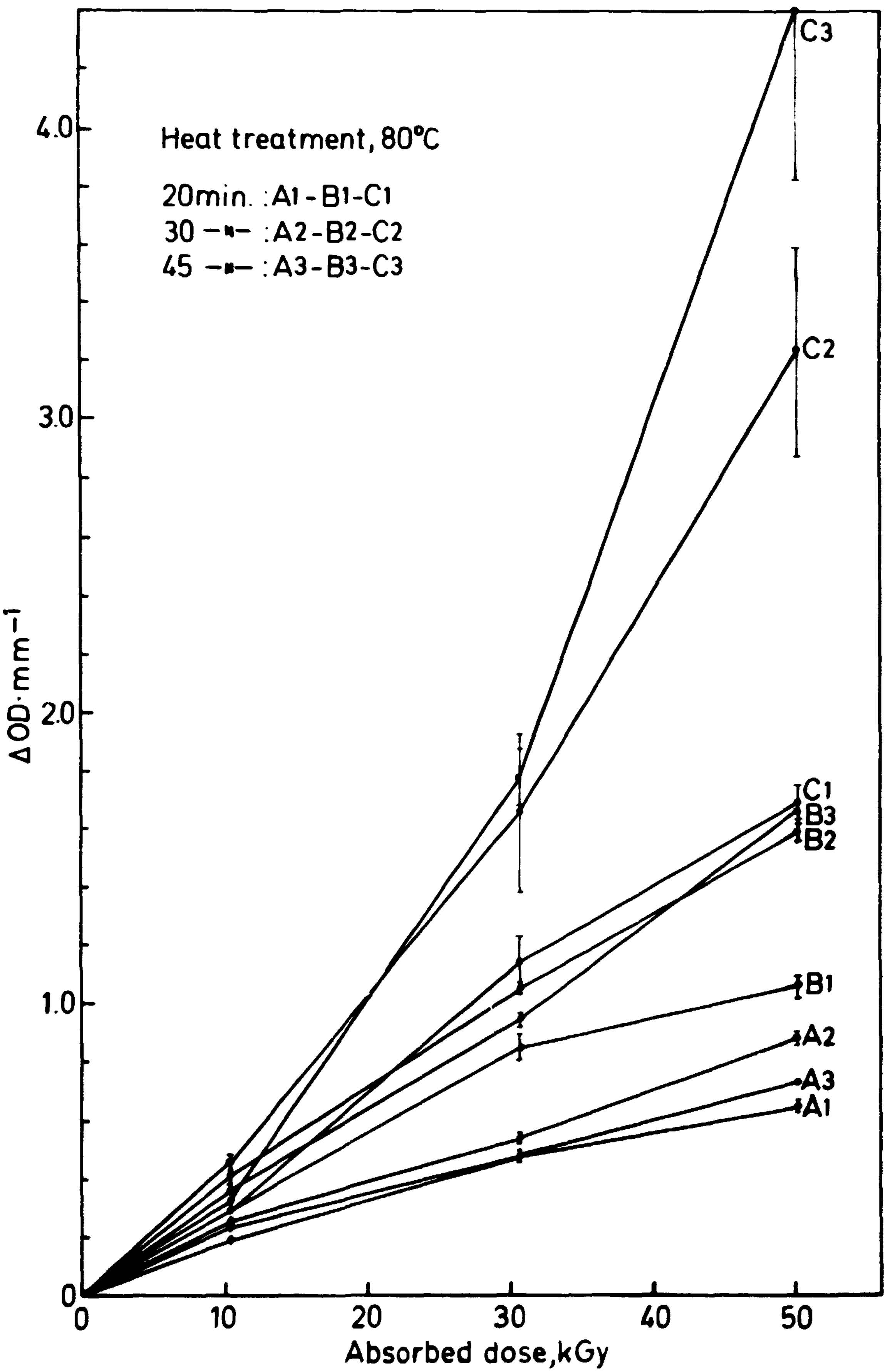

Fig. 3. The effect of different heating times in the post-irradiation heat treatment of the 4 PVC-films. The dose was given in full doses.

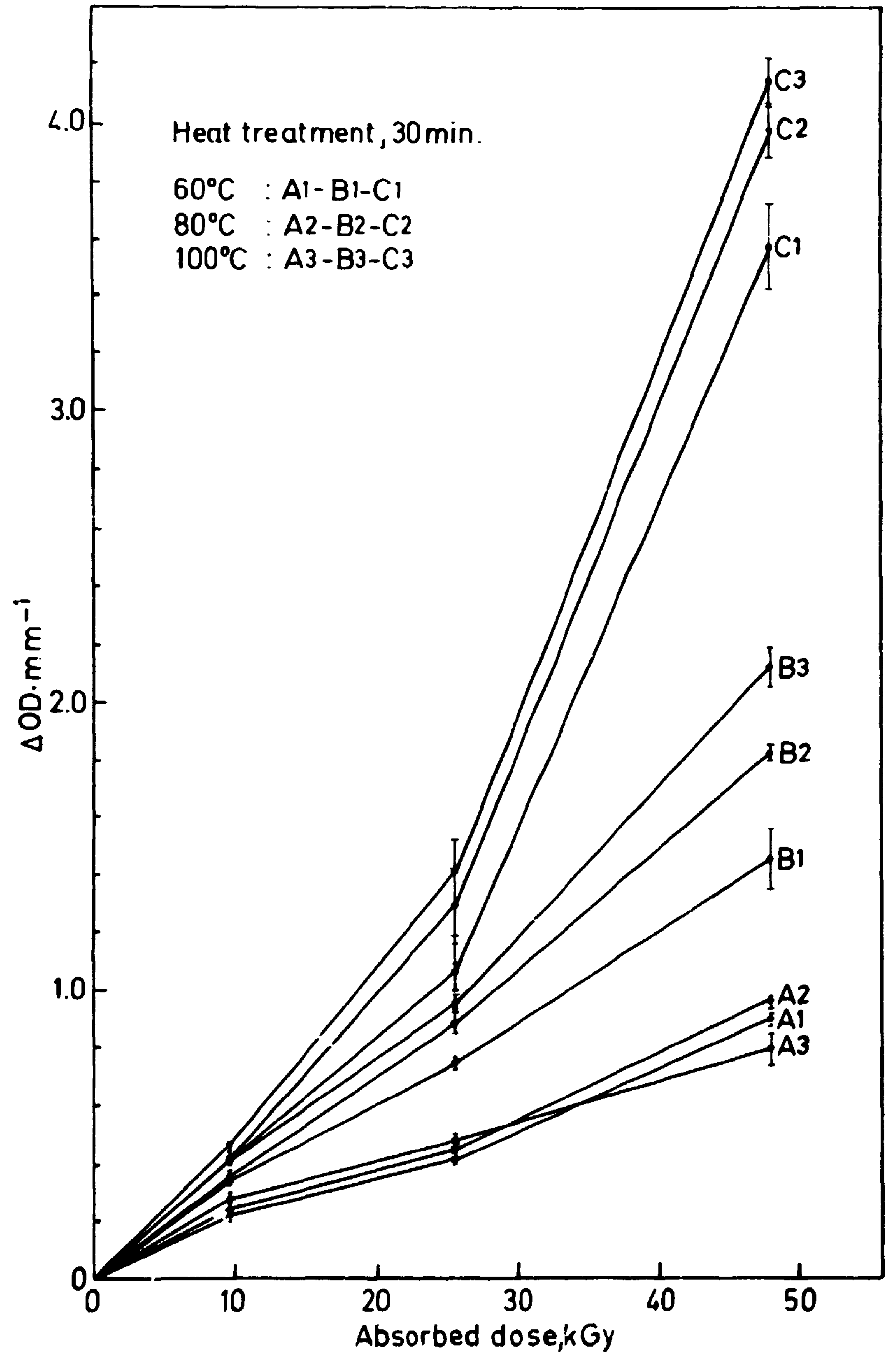

Fig. 4. The effect of different temperature in the post-irradiation heat treatment of the 4 PVC-films. The dose was given in full doses.

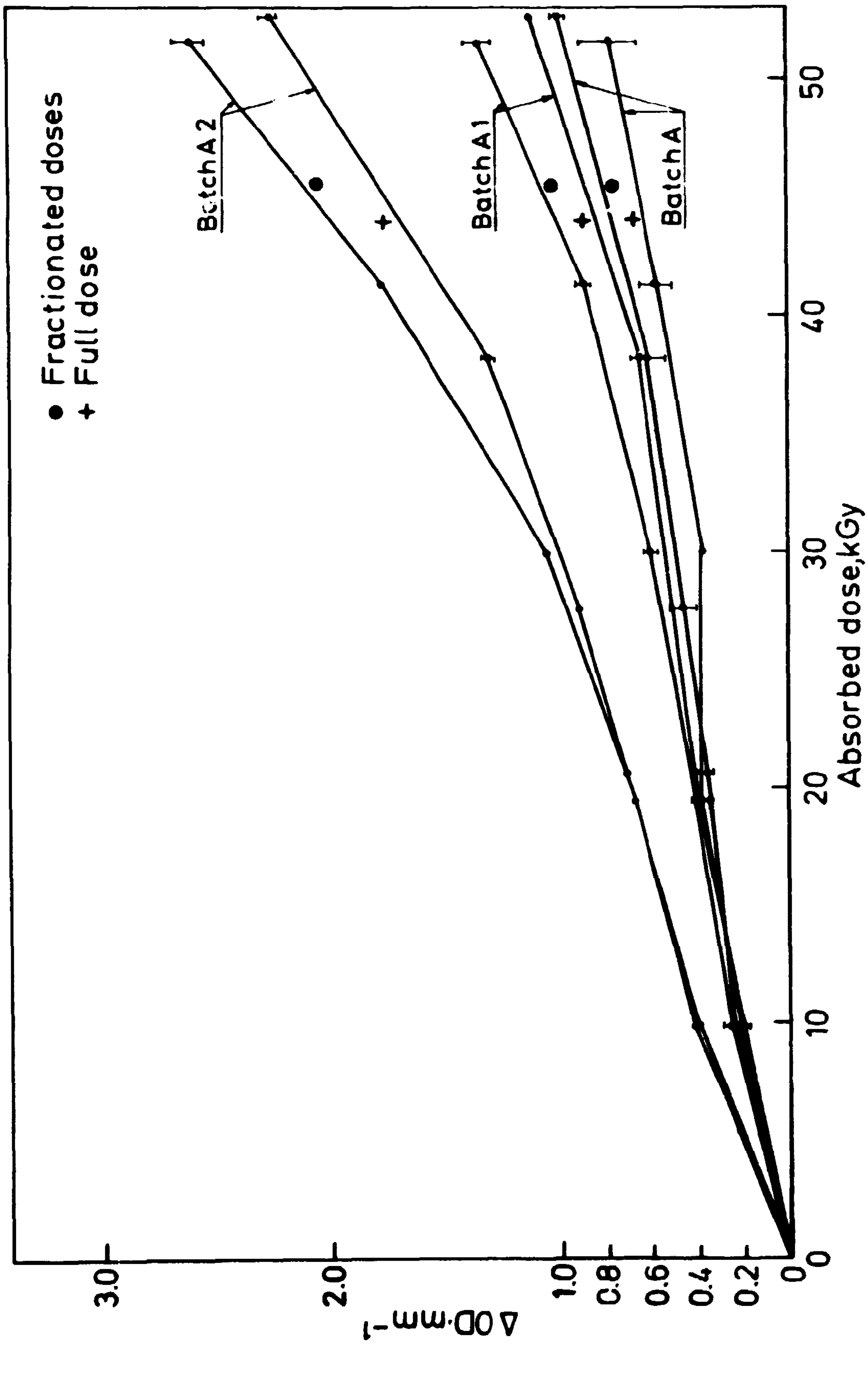

Fig. 5. Change in optical density divided by thickness ($\Delta OD \cdot mm^{-1}$) versus dose for batch A, A-1, A-2.

Risø National Laboratory

Risø - M - 2508

Risø - M - 2508

Title and author(s)

Properties of Commercial PVC-Films with Respect to Electron Dosimetry

Arne Miller and Xie Liqing

12 pages + tables + 5 illustrations

Date May 1985

Department or group

Accelerator

Group's own registration number(s)

Copies to

Abstract

The properties of three commercially available polyvinyl chloride (PVC) film supplies and one made without additives were tested with respect to their application as routine dose monitors at electron accelerators. Dose fractionation was found to increase the response and the post-irradiation heat treatment was very critical for some of the films.

Available on request from Risø Library, Risø National Laboratory (Risø Bibliotek), Forsøgsanlæg Risø), DK-4000 Roskilde, Denmark
Telephone: (03) 37 12 12, ext. 2262. Telex: 43116